lecture 11

MIPS assembly language 4

- functions
- MIPS stack

February 15, 2016

MIPS registers

already mentioned

new today

Name	Register Number	Usage	Preserved on call
$zero	0	the constant value 0	n.a.
$at	1	reserved for the assembler	n.a.
$v0-$v1	2-3	value for results and expressions	no
$a0-$a3	4-7	arguments (procedures/functions)	yes
$t0-$t7	8-15	temporaries	no
$s0-$s7	16-23	saved	yes
$t8-$t9	24-25	more temporaries	no
$k0-$k1	26-27	reserved for the operating system	n.a.
$gp	28	global pointer	yes
$sp	29	stack pointer	yes
$fp	30	frame pointer	yes
$ra	31	return address	yes

functions in C

```
main() {
    int   m, n
    :
    m =   myfunction(n);
    :
}
```

parent / caller

```
int   myfunction (int  j) {
    int   k;
    :
    return  k;
}
```

child / callee

parent must:

- save in Memory any registers it will need later (after return)
- provide arguments to child
- provide return address to child (so child can jump back when done)

- branch to child

child must:

- allocate space for local variables (registers, Memory) and not write over parent's data (registers, Memory)
- compute value and return it to parent
- branch back to parent

parent must:

- branch to child

child must:

- branch back to parent

How?

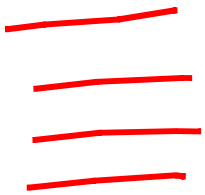
Jump and Link, Jump register

main :

jal myfunction

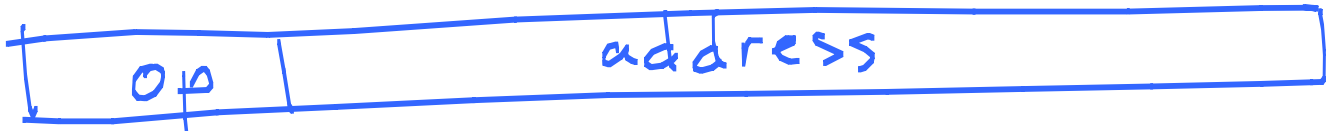
writes address of next instruction into $ra = $31

myfunction :



jr $ra

jal

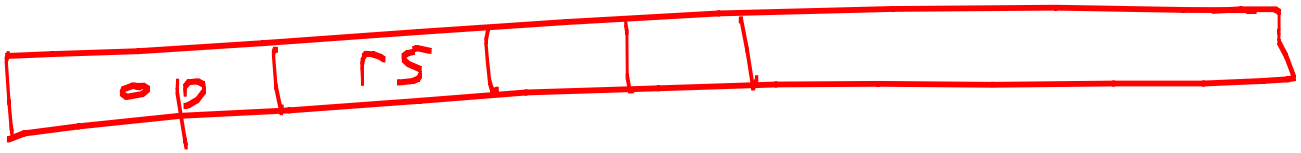


J format

offset address of instruction to jump to

(defined a few lectures from now)

jr



R format

Provide argument(s), return value(s)

How?

$a0, $a1, $a2, $a3 — argument registers

$4, $5, $6, $7

$v0, $v1 — return value registers

$2, $3

provide argument(s)

```
main() {
    int   m, n
    :
    m =   myfunction(n);
    :
}
```

```
move   $a0, $s0
jal    myfunction
move   $s3, $v0
```

return value(s)

```
int   myfunction (int  j) {
    int   k;
    :
    return  k;
}
```

```
move   $v0, $s1
jr     $ra
```

Encapsulation Problem

- author of parent function might not know which $s and $t registers the child uses

- anthor of child function might not know which $s and $t registers the parent uses

Kitchen Policies

① By default, all dishes are clean.
Use dishes, then clean them.

② By default, all dishes are dirty.
Wash what you need and leave them dirty.

Problems arise when two housemates have different policies.

MIPS register conventions (policies)

parent (caller)

- assume that $s0, -- $s7 will contain same values before and after call
- don't assume that $t0, .. $t7 will contain same values after call

(If parent will need values in $t0, .. $t7 after call, then these values must be stored in Memory prior to call, and loaded after call.)

MIPS register conventions

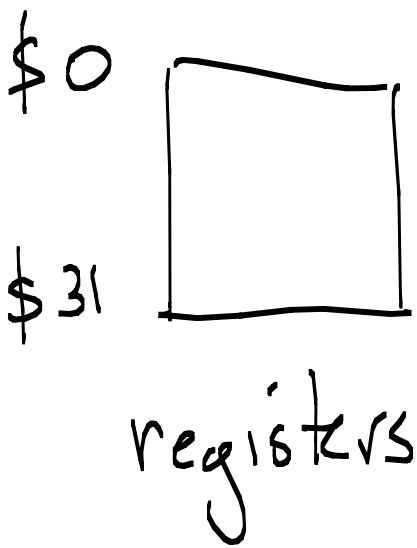
child (callee)

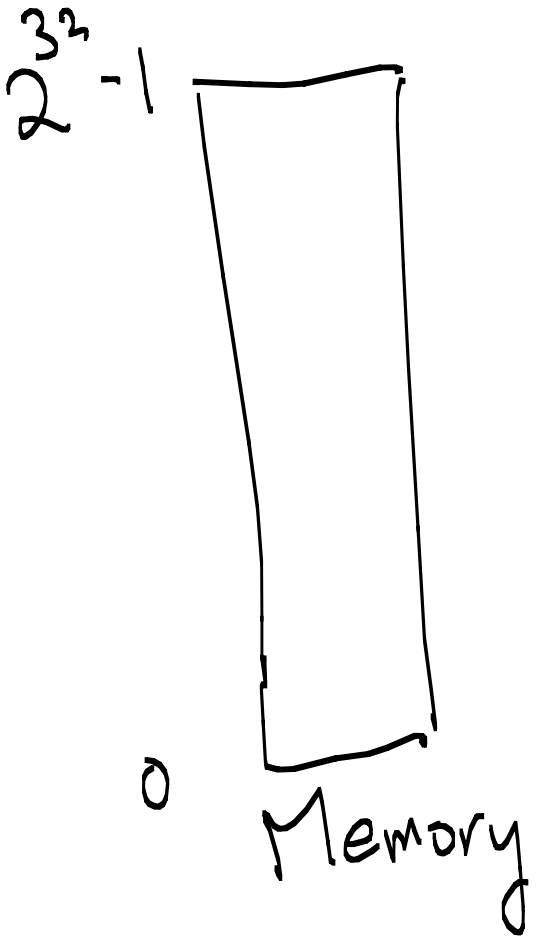
- assume that $t0, -- $t7 are not being used by parent

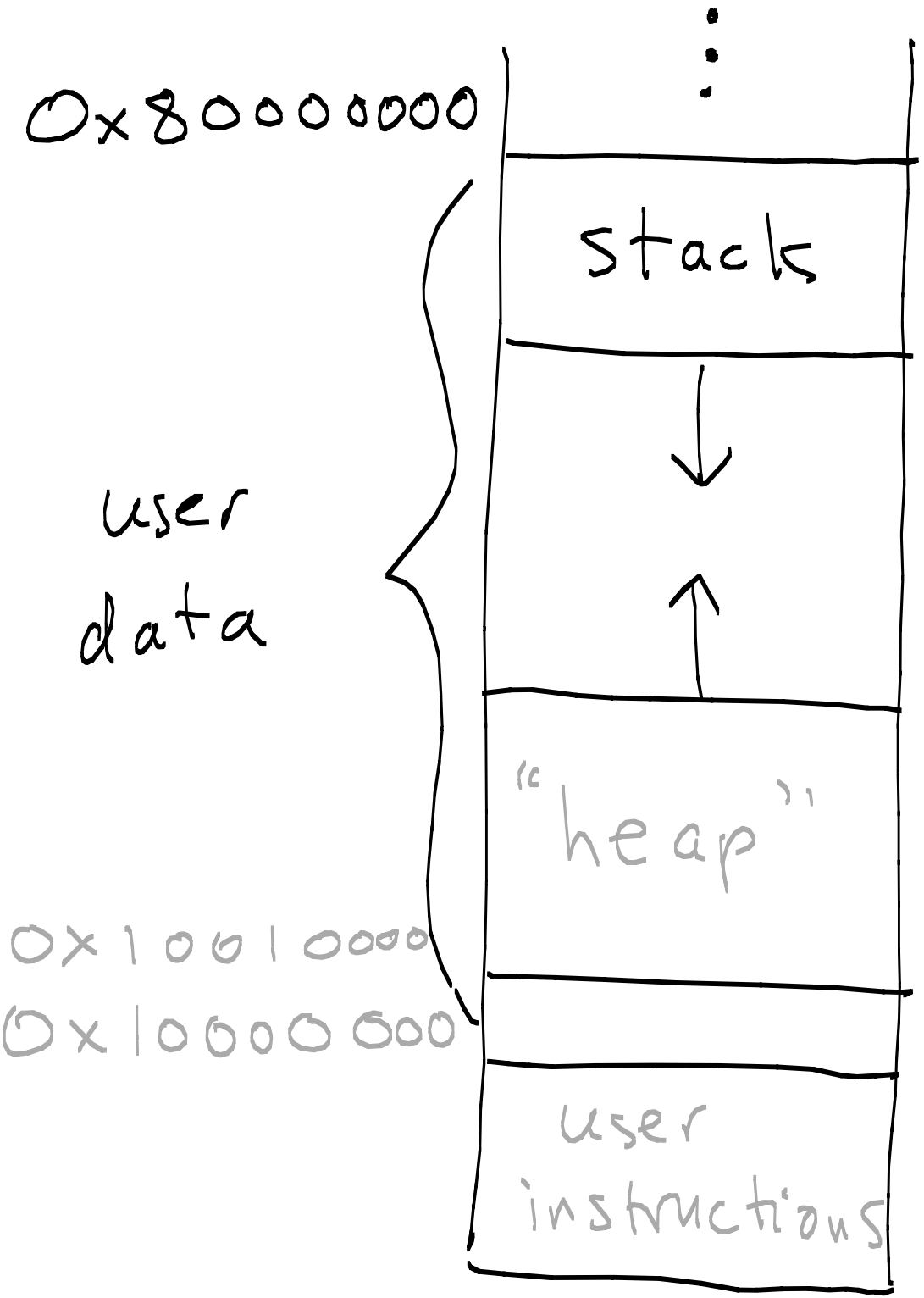
- assume that $s0, -- $s7 are being used by parent.

(If child needs to use any of $s0, .. $s7, then it first needs to store the current values in Memory, and re-load the values prior to returning to parent.)

How and where do functions store register values in Memory?



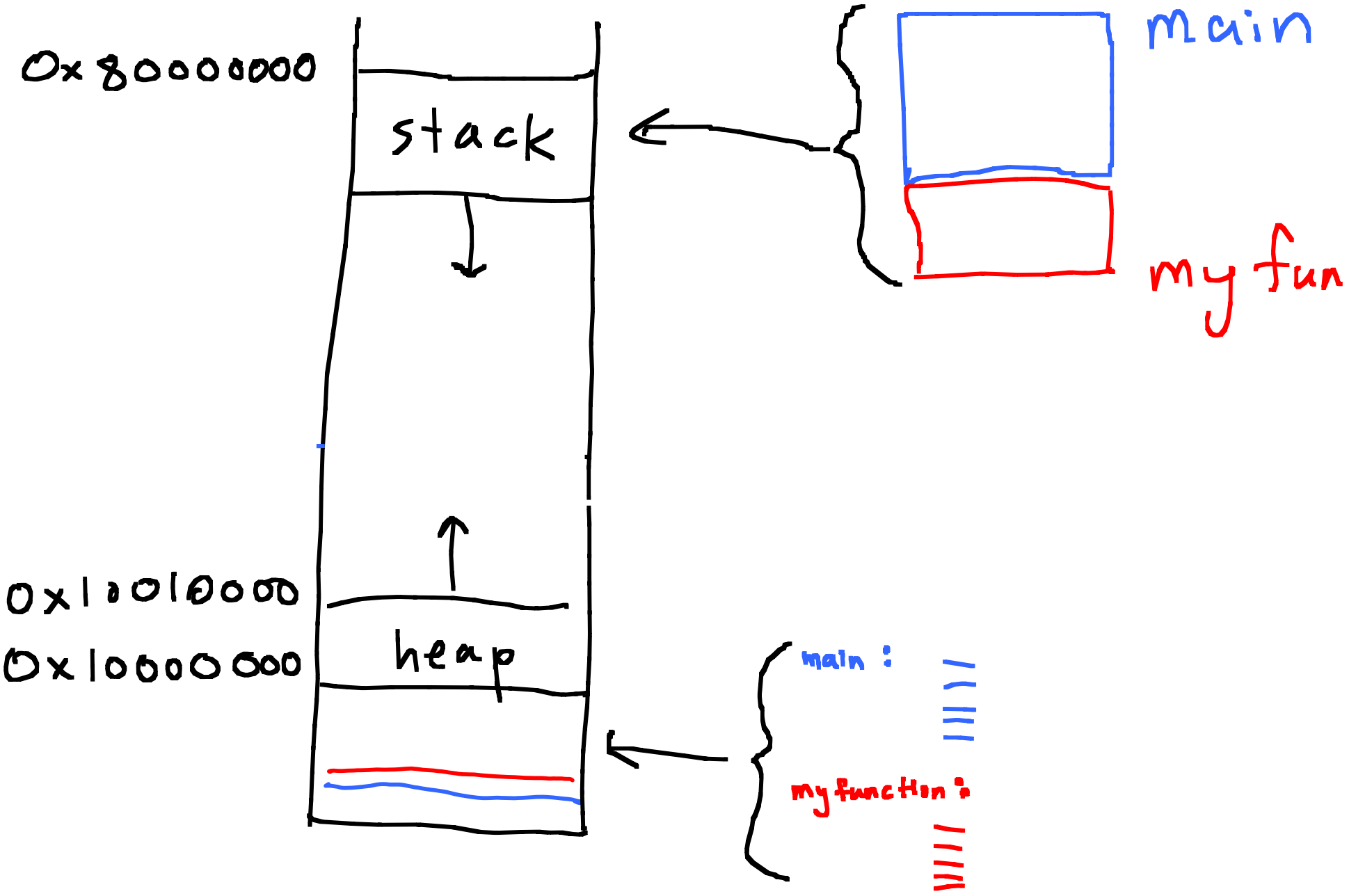


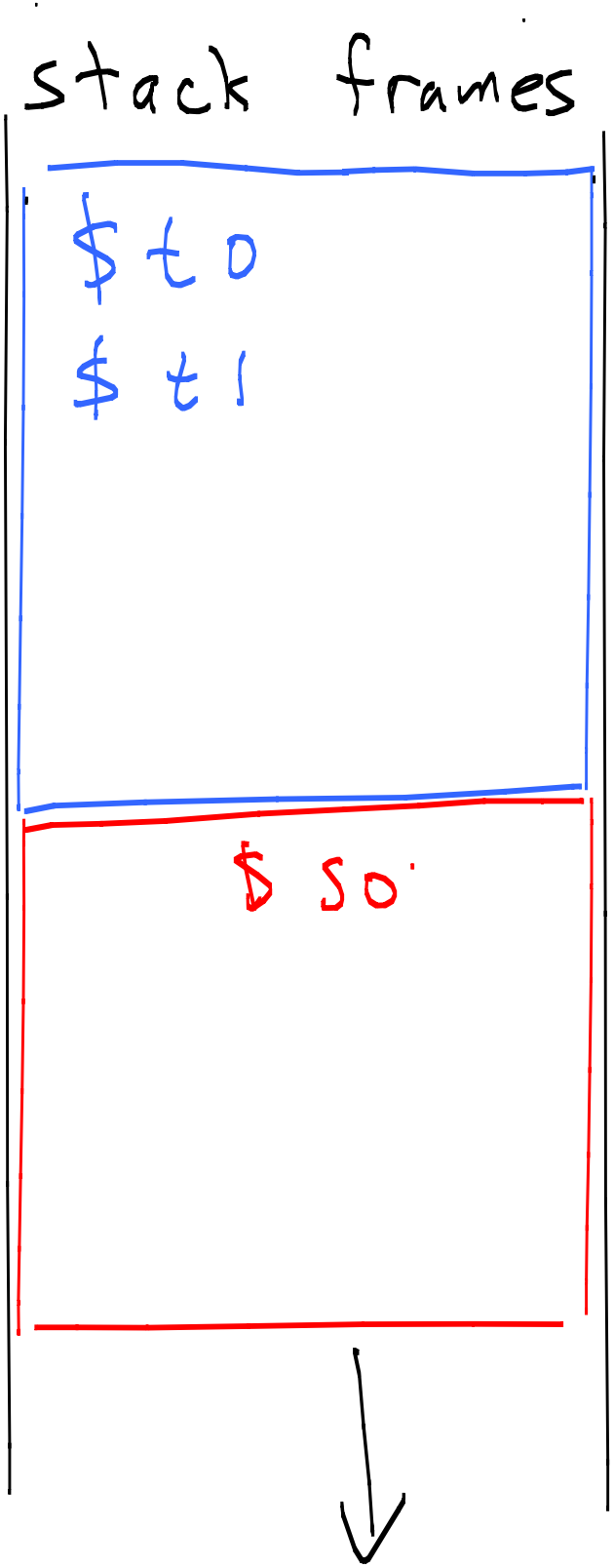


function arguments, local variables, return address, etc

see lecture 10 (also "malloc" for those who know C)

Stack frames



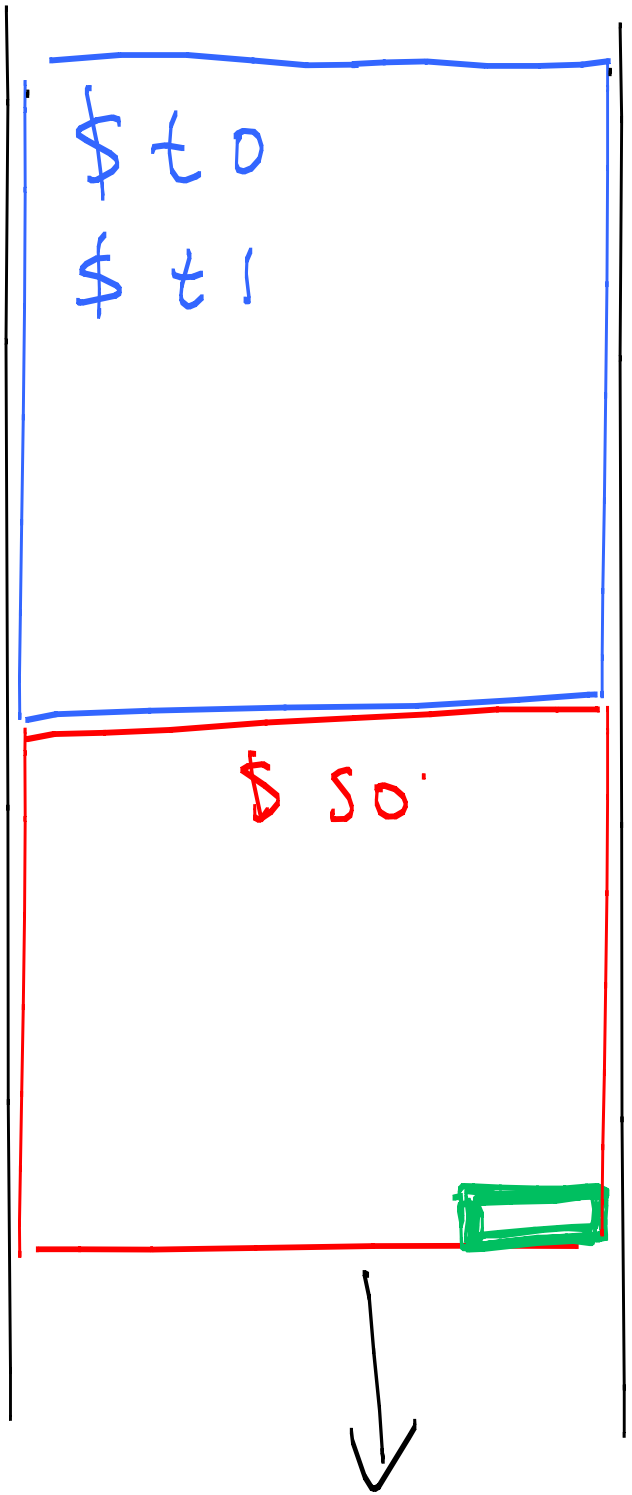


main stores temporary registers before calling myfunction.
(Here we assume variables m and n use $t0 and $t1.)

myfunction stores previous values of any save registers that it will use. (Here we assume variable k uses $s0.)

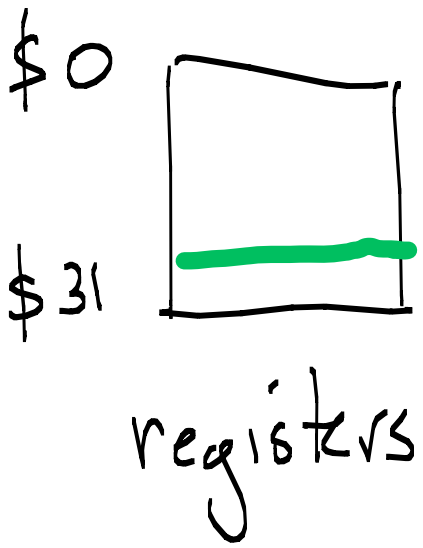
```
main() {
    int  m, n
    :
    m =  myfunction(n)
    :
}


int  myfunction (int j) {
    int  k
    :
    return k
}
```



Stack pointer

Stack pointer (register $sp = $29)
contains the lowest address of the stack.



```
parent :
                :
        addi    $sp, $sp, -8
        sw      $t1, 0($sp)
        sw      $t0, 4($sp)
        jal     child
        lw      $t1, 0($sp)
        lw      $t0, 4($sp)
        addi    $sp, $sp, 8
                :
```

parent :

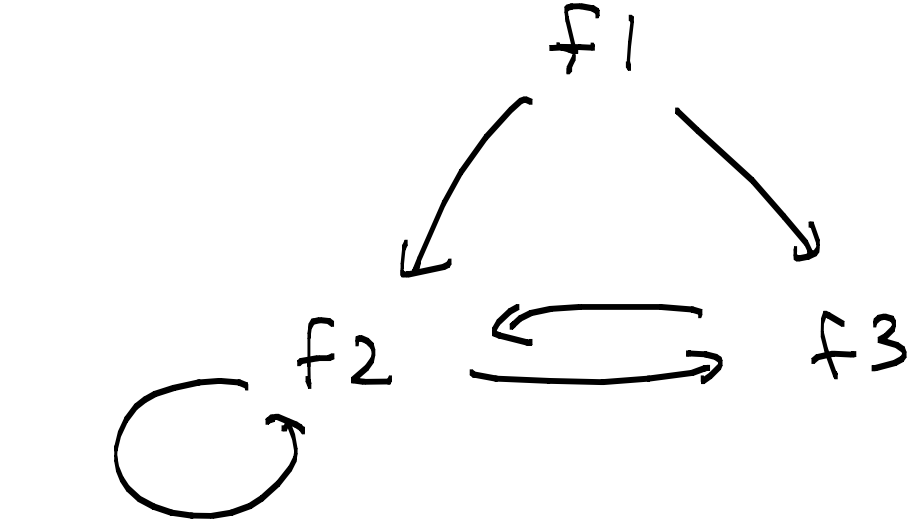
allowed

```
        .
        .
sw      $t0, -4($sp)
sw      $t1, -8($sp)
addi    $sp, $sp, -8
jal     child
        .
addi    $sp  8($sp)
lw      $t1, -8($sp)
lw      $t0, -4($sp)
        .
        .
```

child:

```
addi   $sp, $sp, -4
sw     $s0, 0($sp)
:
lw     $s0, 0($sp)
addi   $sp, $sp, 4
jr     $ra
```

do work here using register $s0



i.e. recursive

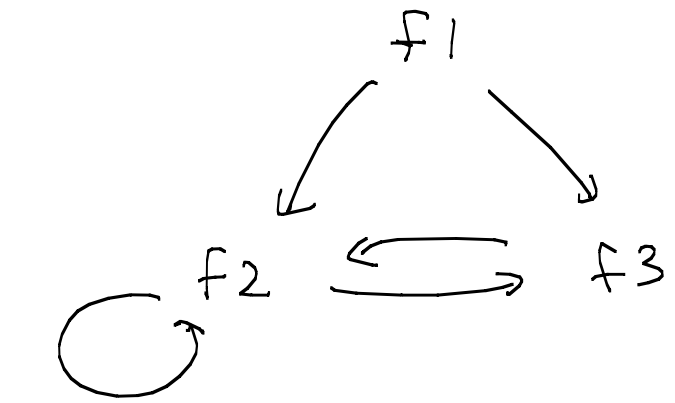
$f_i \longrightarrow$ can call f_j

When functions call another, we need to ensure that data is safe (not written over).

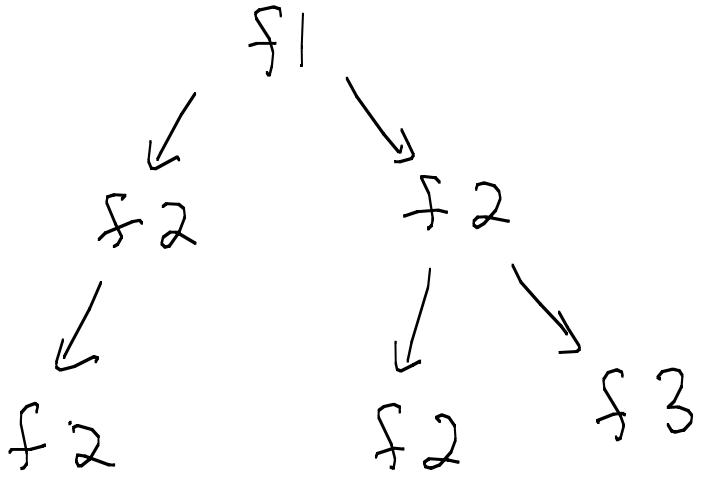
When a function is both a child and a parent, it must store the return address (to its own parent) before it calls its child. It also needs to store $a registers (from parent) that it modifies.

(See conventions on slide 2).

(static, compile time)



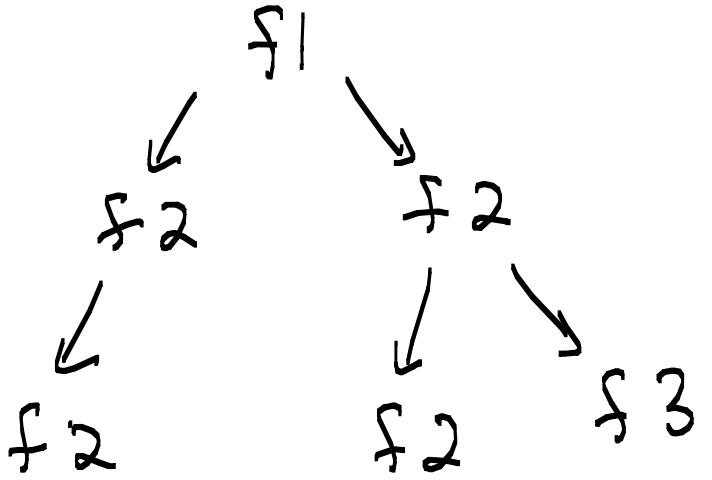
(dynamic, runtime)



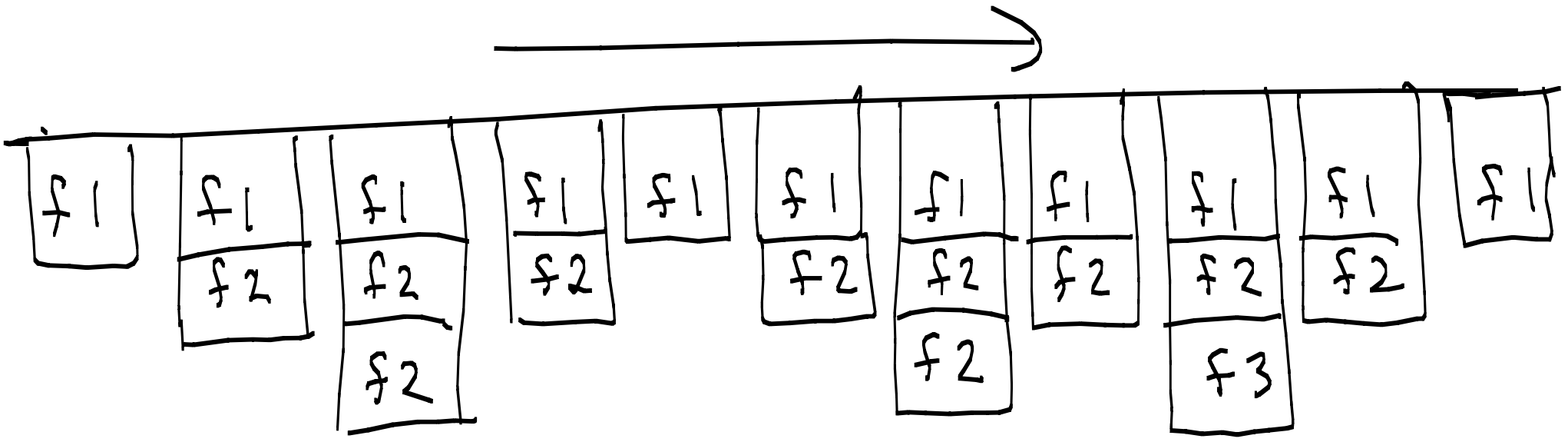
"Call tree"

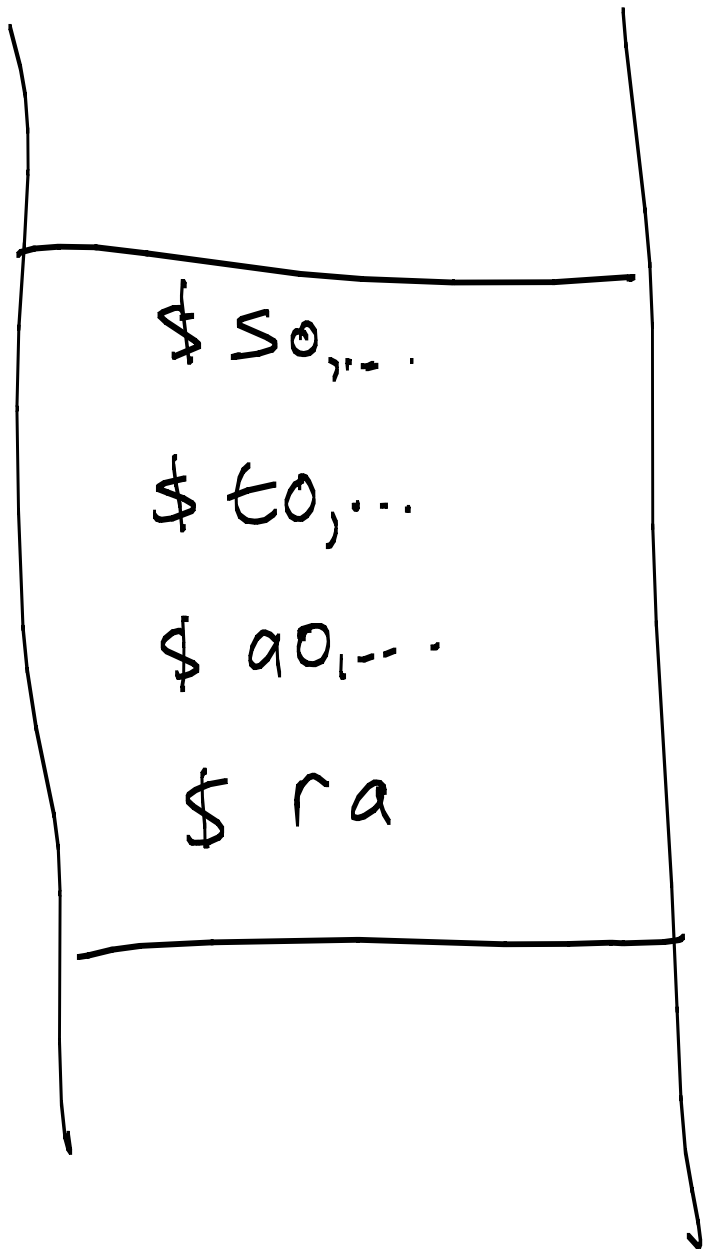
("pre-order traversal" - COMP 250)

Call tree



Evolution of stack over time





stack frame in general case

Example: recursion

```
int sumton(int n){ // n>0
    if (n == 0)
        return 0;
    else
        return n + sumton(n-1);
}
```

```
sumton:
      #  if n == 0 then branch to base case
      # else push the two items onto the stack:
      #   - return address ($ra)
      #   - argument n ($a0)
      #
      # compute (n-1 )  argument for next call
      # jump and link to sumton (recursive)

      # load the return address  (pop)
      # load argument from the stack (pop)
      # change the stack pointer

       # register $v0 contains result of sumton(n-1)
      # add argument n  to $v0
      # return to parent

basecase:
     #  assign 0 as the value in $v0
     # return to parent
```

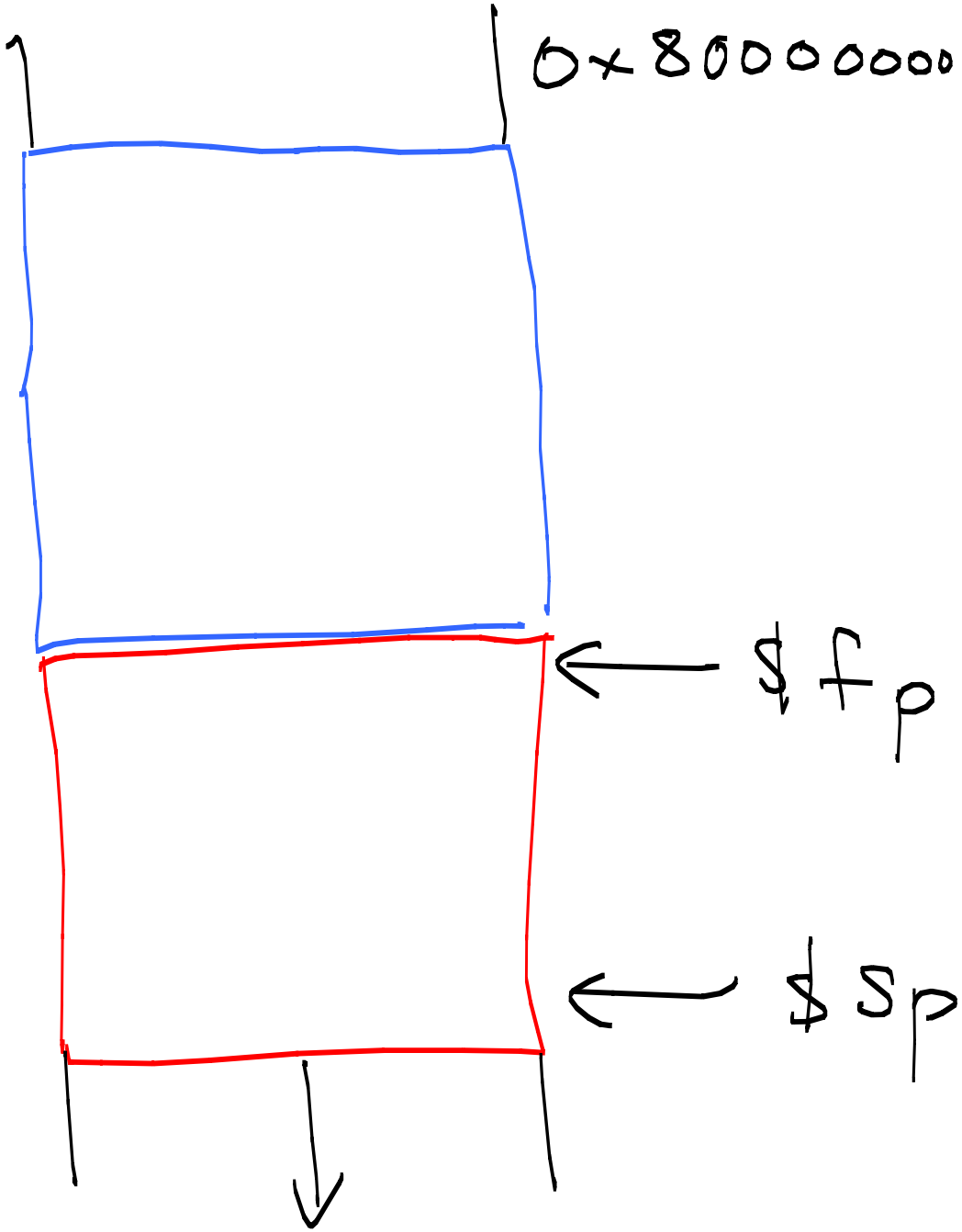
```
sumton:
    beq     $a0,$zero, basecase   #  if n == 0 then branch to base case
    addi    $sp,$sp,-8            # else , make space for 2 items on the stack
    sw      $ra,  4($sp)          # store return address on stack
    sw      $a0, 0($sp)           # store argument n on stack
                                  # (will need it to calculate returned value)
    addi    $a0, $a0, -1          # compute argument for next call:  n = n-1
    jal     sumton                      # jump and link to sumton  (recursive)

    lw      $ra,   4($sp)         # load the return address
    lw      $a0,  0($sp)          # load n from the stack
    addi    $sp,  $sp,8           # change the stack pointer

                                  # register $v0 contains result of sumton(n-1)
    add     $v0, $a0, $v0         # add n  to $v0
    jr      $ra                   # return to parent

basecase:
    addi    $v0,$zero,0           # assign 0 as the value in $v0
    jr      $ra                   # return to parent
```

Frame Pointer ($30)



Sometimes the size of stack frame is not fixed.

It may be useful to keep track of where frame starts.

```
main() {
    int   m, n
    :
    m =   myfunction(n);
    :
}

int   myfunction (int  j) {
    int   k;
    :
    return  k;
}
```

* kernel calls main

Announcements

A2 is due next Sunday at midnight.

A3 will be posted soon and will be due on the last day of Reading Week (~3 weeks from now)

A4 (last one) will be posted in mid-March and due at end of March.

Last lecture is April 13. Final exam is April 26 (tent.)